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(U) *The Effects of Pattern and Color on the Visual Detection of Camouflaged Vehicles,* by Hubert O. Whitehurst. China Lake, Calif., Naval Weapons Center, April 1975. 28 pp. (NWC TP 5746, publication UNCLASSIFIED.)

(U) Two camouflage experiments were conducted in which subjects searched for model armored personnel carriers placed singly on a terrain model. The effects of pattern contours, the number of colors used to paint the patterns, and the particular colors used on search times and detection probabilities were measured. Analyses of variance revealed no significant effects due to pattern contours or number of colors, while color per se was found to have a significant effect on search times. No significant differences were found between search times for an olive drab control target and pattern-painted targets. Search times and far visual acuity were found to be significantly correlated. It was concluded that pattern-painting does not affect target detection difficulty under the conditions tested in these experiments.

NWC-TP-5746

The Effects of Pattern and Color on the Visual Detection of Camouflaged Vehicles

by
Hubert O. Whitehurst
Aircraft Systems Department

APRIL 1975

Naval Weapons Center
CHINA LAKE, CALIFORNIA 93555

Naval Weapons Center

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

R. G. Freeman, III, RAdm., USN . . . . . Commander

G. L. Hollingsworth . . . . . Technical Director

FOREWORD

This report documents work conducted from December 1974 through March 1975 at the Naval Weapons Center, China Lake, Calif., under a target acquisition program supported by MIPR RA 22-74, AMCMS Code 675702.12.86300.

The Joint Technical Coordinating Group for Munitions Effectiveness has established a Target Acquisition Working Group (TAWG) under the Joint Munitions Effectiveness Manual/Air-to-Surface Division. Current TAWG tasks include the description of user experience with target markers, the summary of existing target-aquisition field test data, the description and evaluation of mathematical models of target acquisition by direct vision and electro-optical sensors, quantification of target masking by terrain and vegetation, the relating of terrain type to target acquisition difficulty, and the evaluation of camouflage effects on target acquisition.

This report describes two experiments dealing with the effectiveness of camouflage patterns and colors in preventing air-to-surface target acquisition. The report has been reviewed for technical accuracy by Ronald A. Erickson. It is released at the working level for information only. Work on the effectiveness of camouflage patterns against surface-to-surface target acquisition is continuing.

Released by
PAUL B. HOMER, *Head*
Weapons Systems Analysis Division
4 April 1975

Under authority of
M. M. ROGERS, *Head*
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CONTENTS

INTRODUCTION

The U. S. Army camouflage effort increased substantially in late 1971 with the initiation of a cooperative camouflage program between Headquarters, Modern Army Selected Systems Test, Evaluation and Review (MASSTER) and the U. S. Army Mobility Equipment Research and Development Center (MERDC). This cooperative effort grew out of the realization that the ability to conceal targets had been outstripped by the technology available to detect targets.

In April 1973 a symposium on passive countersurveillance was conducted by MERDC at the Stanford Research Institute, Menlo Part, California. In his introductory remarks, W. B. Taylor spoke of a February 1972, MASSTER-MERDC evaluation of the employment of camouflage techniques and materials at Fort Hood. After a field test had been conducted, it was concluded that unit camouflage performance was poor and comparable to the Army capability at the beginning of World War II.[1]

Not many well-controlled studies have been conducted to evaluate the effect of such variables as pattern color, pattern contour, and number of colors used to paint the pattern, on the degree of difficulty of detecting the target. Some studies have been conducted which show that multicolor patterns are effective in reducing detection probability. Humphreys and Jarvis[2] reported that pattern painting disrupts signature characteristics, reduces target/background contrast, and distorts the vehicle's geometric lines and overall configuration. It was concluded after field tests were conducted that (among other things) camouflage pattern-painting is an effective camouflage technique which reduces visual and near infrared ground target

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[1] Stanford Research Institute. *Proceedings of the Symposium on Passive Countersurveillance*, Menlo Park, Calif., conducted by USAMERDC, April 1973. (Report No. SR1-3-4901, Contract No. DAAK02-73-C-0031, Publication SECRET).

[2] U. S. Army Mobility Equipment Research and Development Center. *Camouflage Pattern Painting Report of USAMERDC's Camouflage Support Team to MASSTER*, by A. H. Humphreys and S. V. Jarvis, Fort Belvoir, Virginia, February 1974. (Report No. 2090, Publication UNCLASSIFIED).

acquisition from ground or air observations. Marrero-Camacho and McDermott[3] also concluded that pattern painting reduces the possibility of detection and recognition of tactical military vehicles. They advocated painting vehicles with the MASSTER-MERDC basic pattern and color combination at the production line.

Not all studies have shown that multicolor patterns are more effective at camouflaging objects than are single colors. In a report on small item camouflage, Bucklin[4] reported that when green objects and brown objects were mixed in the same field, the detection rates dropped to less than one-half the rate for either color of object tested alone. The addition of a third color (straw) resulted in a further drop in the detection rate for the green and straw items but not the brown. It was also found that, when green items and straw items were mixed, detection rates for straw dropped by one-third while the rate for green items more than doubled. Recently, Jarvis[5] reported the results of a preliminary army field test of five pattern-painted vehicles and one olive drab vehicle in which detection and identification ranges were the measure of camouflage effectiveness. An analysis of variance was followed by a post-hoc test which revealed that four patterned vehicles (German, MERDC, Swedish, and USAREUR) were more difficult to detect than both an olive drab vehicle and a vehicle painted with a British pattern. No differences were found among the German, MERDC, Swedish, or USARERU pattern-painted vehicles or between the solid olive drab and the British pattern-painted vehicles. These results could be considered inconclusive, however, because of the high significance level used (0.10). Such results could occur by chance ten percent of the time.

At this point it seems that the evidence to support pattern-painting as an effective camouflage technique is inconclusive. The two experiments documented in this report were conducted to contribute laboratory type data and to shed some additional light on the effects of pattern-painting.

[3]Combat Service Support and Special Programs Directorate Headquarters, MASSTER. *Camouflage Evaluation Report (Phase I)*, by Maj. G. Marrero-Camacho and Maj. R. B. McDermott, Fort Hood, Texas, January 1974.

[4]Stanford Research Institute. *History and Status of Small Item Camouflage*, by B. L. Bucklin, U. S. Army, Picatinny Arsenal, Dover, New Jersey. In Proceedings of the Symposium on Passive Countersurveillance, Menlo Park, Calif., conducted by USAMERDC, April 1973. (Report No. SR1-3-4901, Contract No. DAAK 02-73-C-0031, Publication SECRET).

[5]U. S. Army Mobility Equipment Research and Development Center. *Technical Memorandum: Fort Knox Test of Camouflage Pattern Effectiveness*, by S. V. Jarvis, Fort Belvoir, Virginia, August 1974. (Publication UNCLASSIFIED).

NOMENCLATURE

Certain terms related to camouflage have not been defined and agreed upon. For this report, definitions of some of the terms will be as follows:

1. Pattern Element - An area on the surface of an object which is defined by its unique perimeter, size, and color.

2. Pattern Contour - The shape of the lines which mark the perimeter of a pattern element.

3. Pattern - An overall camouflage technique, including pattern contour, size, color, and the number of colors used to form all the pattern elements.

OBJECTIVES

The objectives of the two experiments reported here were to determine if pattern contours, the number of colors used to paint the pattern elements, and the actual colors used affect observers' ability to detect military vehicles.

The main hypotheses tested in Experiment I were that:

1. Pattern contours affect search times and detection probability, and

2. The number of colors used to paint the pattern elements affects search times and detection probability.

The first hypothesis, plus the additional hypothesis that the actual colors used to paint the pattern elements affect search times and detection probability were tested in Experiment II.

EXPERIMENT I

METHOD

Scale model armored personnel carriers (APC's) were pattern-painted and placed singly on a terrain model. The terrain model consisted of green

ground cover with assorted trees, sand, and rocks. Subjects were required to search the terrain model and find the target. Search times and the number of target detections indicated the relative effectiveness of the different patterns.

Design

A 2 x 3 x 6 factorial design was used to test the effect of pattern contours (2), the number of colors used in painting the pattern elements (3), and target locations (6) on search times and the probability of correct target detection (Table 1). The subjects were divided into two groups to test the pattern contours effect. One group searched for APC's painted with MERDC-type pattern contours while the other group searched for APC's painted with Swedish-type pattern contours. The three vehicles each subject searched for, were presented at simulated ranges of approximately 425 meters and 550 meters. The APC's were painted one color, three colors, and four colors. Each subject received a total of 24 trials [3 vehicles x (2 practice trials + 6 data trials)].

Table 1. The Design for Experiment I.

		Number of Colors															
		1						3						4			
		Location						Location						Location			
		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Pattern Contour	MERDC	Subject Group 1																	
	Swedish	Subject Group 2																	

Subjects

Twenty-four employees at the Naval Weapons Center (14 male and 10 female) served as subjects in the experiment. All subjects had normal color vision and binocular visual acuity of 20/20 or better.

Apparatus

Search Area. The search area was an eight foot square terrain model. Most of the surface was covered with small grains of styrofoam painted various shades of green to represent grass and underbrush. Trees, varying in height from approximately 4 feet to 41 feet (simulated) and in simulated density from approximately 20 to 60 trees per 100 foot square area, provided most of the clutter. A few small rocks were also placed on the terrain model to provide color variation and false targets.

The slant ranges from the terrain model to the subject varied from 15 feet to 23 feet, simulating actual slant ranges of 378 meters to 580 meters. The subject to target depression angles varied from a minimum of 14 degrees to a maximum of 19 degrees below the horizon.

The luminance of the terrain model varied between 6 and 15 foot-lamberts. The luminance of the six locations used for target placement varied between 7 and 12 foot-lamberts.

Lighting. Lighting was provided by two Berkey-Colortran Model 100-412 lights which contained 1000 watt bulbs. A light diffuser and a dichroic filter were attached in front of each light. Additional lighting was provided by fluorescent lights attached to the ceiling above the terrain model. The lighting appeared to simulate a bright, overcast day in which shadows are present but are barely visible. The location of the lights relative to the subject and terrain model is shown in Figure 1.

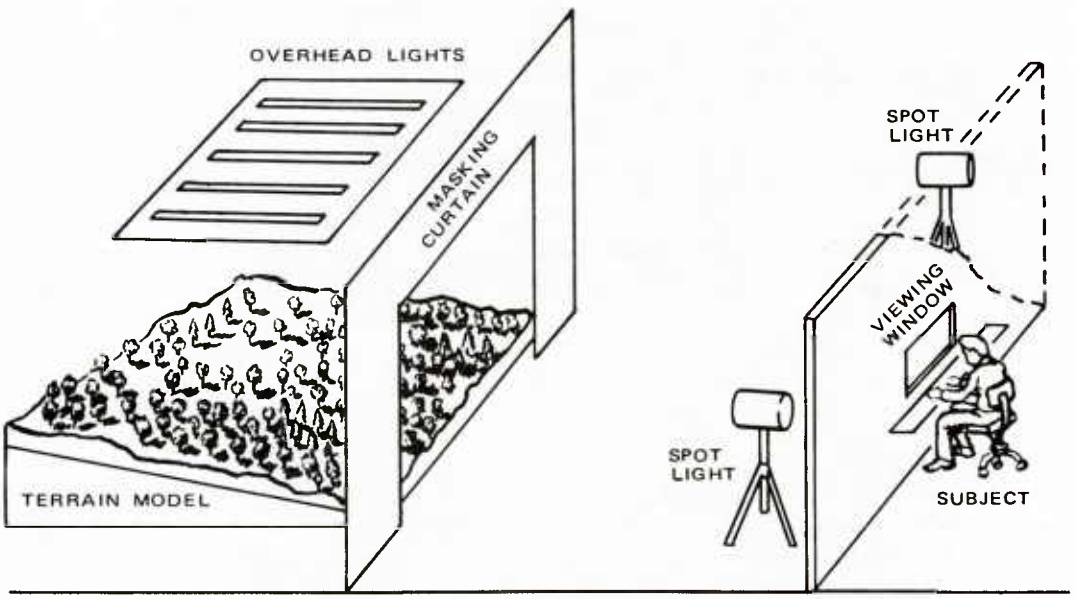

Figure 1. Sketch of the Experimental Apparatus.

Targets. Five 1:84 scale model APC's, subtending from 23 to 29 minutes of arc at the subjects' eyes, depending on the target location on the terrain model, were used in this experiment. The nomenclature used to designate the targets is contained in Table 2. Photographs of the targets and a portion of the terrain model are shown in Figure 2. The recommendation of the U.S. Army Mobility Equipment Research and Development Center[6] was followed when the MERDC contours were painted. A few extra black and straw marks were added to keep the amount of black and straw on the APC's painted with MERDC pattern contours and Swedish pattern contours relatively the same. Also, except for black, the colors used were not the ones actually specified.

Table 2. Target Designation Nomenclature.

Target Name	Target Description
FG	Solid Forest Green Color.
M3	MERDC Pattern Contours Employing 3 Colors
M4	MERDC Pattern Contours Employing 4 Colors
S3	Swedish Pattern Contours Employing 3 Colors
S4	Swedish Pattern Contours Employing 4 Colors

Subject Room. During the experiment, each subject was seated in a room in which all walls and the ceiling were covered with acoustical tile. An 11-3/4 x 13-1/4 inch opening was cut out of the wall which faced the terrain model. The center of the opening was 3 feet 8 inches above the floor. A shelf upon which subjects could place their elbows was located just below the opening.

[6]U. S. Army Mobility Equipment Research and Development Center. *Camouflage Pattern Painting*, designed by the Countersurveillance and Topographic Division, Fort Belvoir, Virginia, June 1974. (UNCLASSIFIED)

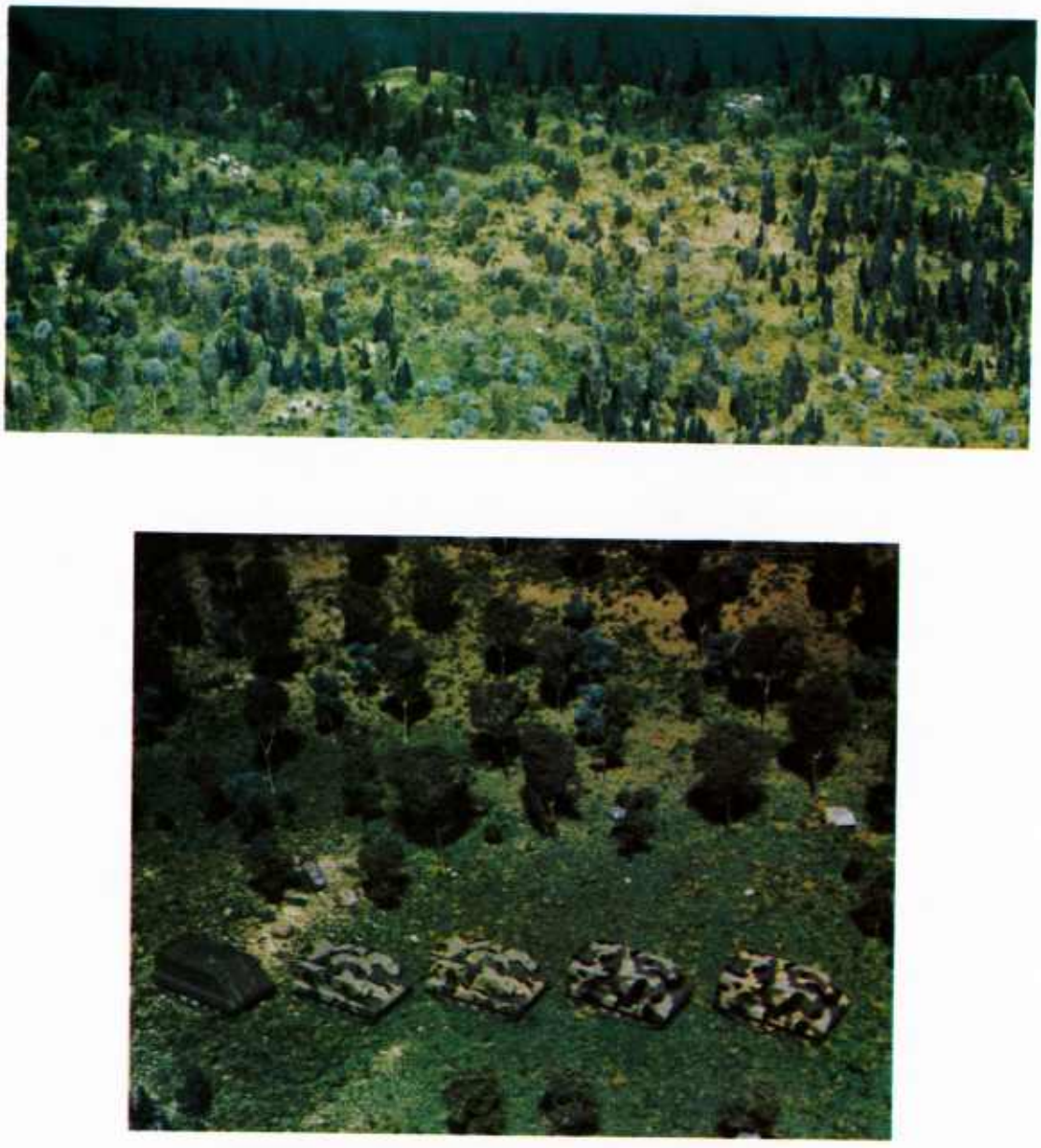

Figure 2. Photographs of the Terrain Model at Two Ranges. The APC's in the Lower Photograph are, from Left to Right, FG, M3, M4, S3, and S4.

Shutter and Timer. A shutter was constructed by attaching a square piece of opaque plastic to the outside of the wall facing the terrain model. It completely covered the opening and served to mask the subject's view of the terrain model between trials. The subject could lower the shutter by pulling a string inside the subject room. The lowered shutter started a timer which measured search times with accuracy to the nearest tenth of a second. The subject could stop the timer by flipping a switch located on the shelf.

Vision Testing. A Bausch and Lomb Armed Forces Vision Tester was used to measure each subject's binocular visual acuity. Dvorine Pseudo-Isochromatic Plates were used to screen subjects for color deficiencies.

Procedure

Each subject was accepted for participation in the experiment only after it had first been determined that the subject's near and far, binocular visual acuity was 20/20 or better and that the subject's color vision was normal.

After the screening phase was completed, the subject was seated in the subject room and instructions were read. It was not necessary to read a complete set of instructions since each subject who participated in this experiment had participated in a similar one, using the same terrain model and procedure, just a few minutes earlier. Both sets of instructions are in Appendix A.

After the instructions were read, the first of the three APC's to be presented was placed on the terrain model. A flap just above the shutter was then dropped, allowing the subject to accommodate on a green colored figure above and behind the terrain model. After about two seconds had elapsed, the subject pulled the string, dropping the shutter, and began searching for the target. The subject flipped the switch on the shelf, stopping the timer, when the target was detected and then verbally stated the location of the target as one of six possible sections of the terrain model. The subject was then allowed to watch the experimenter walk to the target and pick it up. This gave the subject a chance to let the experimenter know if he had made an incorrect detection but had named the correct section. The experimenter then pulled up the shutter to mask the subject's view, and placed the target in another location on the terrain model. The subject was allowed ten seconds to detect the target. If no detection was made in the time allowed, a ten second search time was recorded.

Each target was presented to each subject eight times in succession. The first two trials for each target were practice trials. For these trials, the target was placed in one of many possible locations. For the experimental trials, the target was placed in one of six possible, pre-selected locations such that the target was at a 45 degree angle to the subject and was approximately 1/3 masked. Each target was randomly placed in each

of the six locations. The order of presentation of the three targets was completely counterbalanced between subjects; each target both preceded and followed each of the other targets an equal number of times (twice for this experiment).

Between trial times, the time required to move the target from one location to another, varied from 10 to 15 seconds. The total time required to "run" each subject was about 12 minutes.

RESULTS

The data collected in this experiment do not support the hypotheses that pattern contours and the number of colors used to paint the pattern elements have a significant effect on the difficulty of detecting the targets with unaided vision. Target location was found to significantly affect search times.

Figure 3 gives an overall picture of the results. It shows cumulative percent targets detected as a function of search time. Search times were averaged across locations and subjects.

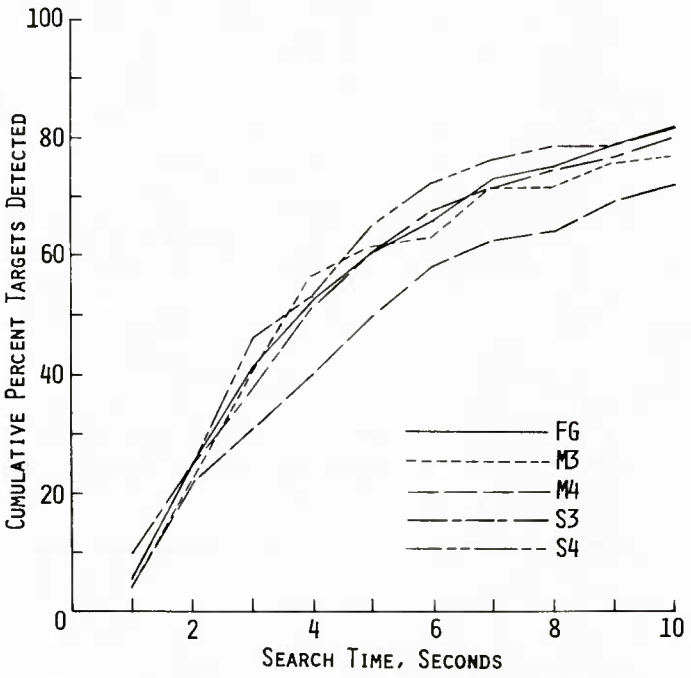

Figure 3. Cumulative Percent Targets Detected as a Function of Search Time.

An analysis of variance of search times revealed no significant effects from pattern contours or number of colors (Table 3). Target locations were found to significantly affect search times. None of the two-way or three-way interactions were significant.

Table 3. Analysis of Variance of Search Times.

Source of Variation	df	MS	F
Pattern Contour (P)	1	3.24	NS
Subjects	11	43.01	NS
Error P	22	44.62	
Number of Colors (N)	2	3.26	NS
P x N	2	24.21	NS
Error N	44	8.34	
Locations (L)	5	188.76	26.21*
P x L	5	11.78	NS
Error L	110	7.20	
N x L	10	10.42	NS
P x N x L	10	6.67	NS
Error NL	220	6.23	

*$p < .01$
NS = Not Significant

Table 4 gives the mean search times at each of the six locations of the terrain model. A Newman-Keuls test of all possible comparisons of mean search times was also computed and the results are included as part of the table.

Table 4. Mean Search Time in Seconds for Each of the Six Locations. All location comparisons were significantly different from one another ($p < .01$) with the exception of the two comparisons indicated by arrows.

5.61	7.48	5.71
3.98	2.83	4.42

Two t-tests of methodological interest were computed. One test was between the mean search times for the first and last six trials each subject received, the other was between the mean search times for men and women. Neither test revealed significant differences in mean search times. Therefore, trial-to-trial learning was minimal and there were no differences in mean search times due to sex.

Table 5 presents mean search times and standard deviations across all subjects, targets, and locations. The table shows what the mean search time and standard deviation were after 24 trials per subject (this experiment) and what the mean and standard deviation would have been if fewer trials had been given. The mean decreases slightly with increases in the number of trials while the standard deviation decreases rather rapidly, dropping 40 percent in this example.

Table 5. The Effect of the Total Number of Trials Given Each Subject on the Mean Search Time and Standard Deviation.

Number of Trials	Mean (Sec)	Standard Deviation
2	5.65	2.58
4	5.65	2.28
6	5.37	2.13
10	5.46	1.68
16	5.32	1.65
24	5.23	1.43

DISCUSSION OF RESULTS

The data collected in this experiment indicate that, under diffuse lighting conditions, the MERDC and Swedish pattern contours are equally effective. Also, for the conditions that existed in this experiment, multicolor vehicles are no more difficult to detect than solid color vehicles. It is important to note that pattern color and pattern size were held relatively constant in this experiment. Differences in pattern-painted vehicles obtained in field tests may be attributable to the fact that pattern color and size were allowed to vary.

It was not surprising that target locations on the terrain model were significantly different. Differences in luminance between the front and back of the terrain model surely accounted for part of the variance. Most of the rest can be attributed to such differences as terrain color and texture, and the color, texture, and size of the trees at different locations. There was probably no range effect per se, since the angular subtense of the targets was well above threshold at both ranges.

The table showing the effect of the total number of trials given each subject on search times and standard deviations was included to provide data for others who may conduct similar experiments. In this experiment, the trial-to-trial learning effect was minimal. If the learning effect can be balanced, a primary consideration in the determination of the number of trials per subject should be the level of error variance which is tolerable.

EXPERIMENT II

METHOD

The methodology for this experiment did not differ substantially from the methodology used in Experiment I. Model APC's were placed singly on the same terrain model and subjects searched for them. The dependent measures were the same.

Design

A 2 x 3 x 9 factorial design was employed to test the effect of pattern colors (2), pattern contours (3) and target locations (9) on search times and detection probability (Table 6). The subjects were divided into two groups to test the pattern color effect. Group 1 subjects searched for patterned vehicles that had a base coat of flat green paint while Group 2 subjects searched for patterned APC's that had a base coat of flat dark olive paint. A third group of subjects (not shown in the table) were included as a control group. They searched for an olive drab vehicle only. Each subject in groups 1 and 2 received a total of 33 trials [3 vehicles x (2 practice trials + 9 data trials)]. Each subject in the control group received 13 trials (4 practice trials + 9 data trials).

Subjects

Thirty-six employees at the Naval Weapons Center (32 male and 4 female) served as subjects. All subjects had normal color vision and near and far, binocular visual acuity of 20/20 or better. None of the subjects had seen the terrain model prior to the experiment.

Table 6. The Design for Experiment II.

		Pattern Contours		
		MERDC	British	German
		Location	Location	Location
		1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
Pattern Color*	Green	Subject Group 1		
	Dark Olive	Subject Group 2		

*Four different colors were used to paint the pattern elements but the base colors were flat green or flat dark olive.

Apparatus

With the exception of the targets, the same apparatus that was used in Experiment I (search area, lighting, subject room, shutter and timer, and vision testing apparatus) was used in this experiment without significant changes being made.

The targets were seven 1: 84 scale model APC's which subtended from 34 to 42 minutes of arc at the subject's eyes, depending on the target location on the terrain model. The nomenclature used to designate the targets is shown in Table 7. Figure 4 is a photograph of the APC's on the terrain model. Four colors were used to paint the pattern elements of all patterned targets.

Procedure

Each subject's near and far binocular visual acuity and color vision were tested. If the subject passed the test, he was seated in the subject room and tape recorded instructions were played (Appendix B).

Table 7. Target Designation Nomenclature. Luminance was Averaged Over Locations.

Target	Target Description	Average Luminance Foot-Lamberts
OD	Solid Olive Drab Color	5.2
MG	MERDC Pattern Contours With Basic Coat of Flat Green	9.1
BG	British Pattern Contours* With Basic Coat of Flat Green	8.5
GG	German Pattern Contours* With Basic Coat of Flat Green	7.8
MO	MERDC Pattern Contours With Basic Coat of Flat Dark Olive	6.6
BO	British Pattern Contours* With Basic Coat of Flat Dark Olive	6.5
GO	German Pattern Contours* With Basic Coat of Flat Dark Olive	6.5

*The actual British and German patterns call for only two colors. Four colors were used in this experiment to keep the number of colors of each APC constant and to hold the range of pattern element sizes relatively constant.

Figure 4. A Photograph of the APC's on the Terrain Model. Appearing in Order from Left to Right are OD, MG, BG, GG, MO, BO, and GO.

After the instructions were played, the first target the subject was to search for was placed on the front of the terrain model to give him a chance to see the target against the background. After about five seconds had elapsed, the shutter was raised to mask the subject's view and the target was placed in one of nine pre-selected locations (simulating ranges of 425, 490, and 550 meters) such that it was completely unmasked. The subject was allowed to visually accommodate on a green figure located above and behind the terrain model. After about two seconds had elapsed he dropped the shutter, searched for the target, and flipped the switch upon detecting it. After flipping the switch, the subject named the section of the terrain model where the target was detected. The subject was provided a square sheet of paper divided into six sections for this purpose. Immediately after the location was named, the shutter was pulled up to mask the subject's view and the target was placed in another location. The subject was allowed ten seconds to detect the target. If no response was made in the time allowed the search time was recorded as ten seconds.

Each subject in groups 1 and 2 searched for each of three targets eleven times in succession. The first two trials for each target were practice trials. The subjects in the control group searched for only one target with the first four trials being practice trials. The order of presentation of the targets and the time requirements were the same as they were in Experiment I except that the targets were randomly placed in nine locations instead of six.

RESULTS

The data collected in this experiment do not support the hypothesis that pattern contours affect the degree of difficulty subjects have in detecting pattern-painted vehicles with unaided vision. The hypothesis that the actual colors of the pattern elements affect search times was confirmed. The dark olive patterned targets were found to be significantly more difficult to detect than the green patterned targets. There was no significant difference between the olive drab target and either of the two groups of patterned targets. Target location was again found to significantly affect search times.

Figure 5 shows the cumulative percent targets detected as a function of search time averaged across locations and subjects.

The results of an analysis of variance of search times revealed no significant pattern contours effect (Table 8). The main effects of pattern colors and locations, and the pattern colors x locations interaction were all significant. A t-test which allows more than one test of significance between experimental groups and a control group[7] revealed no significant difference between the olive drab target and the dark olive patterned targets, nor between the olive drab target and the green patterned targets.

[7]Winer, B. J. *Statistical Principles in Experimental Design*, New York, McGraw-Hill, 1962, p. 264.

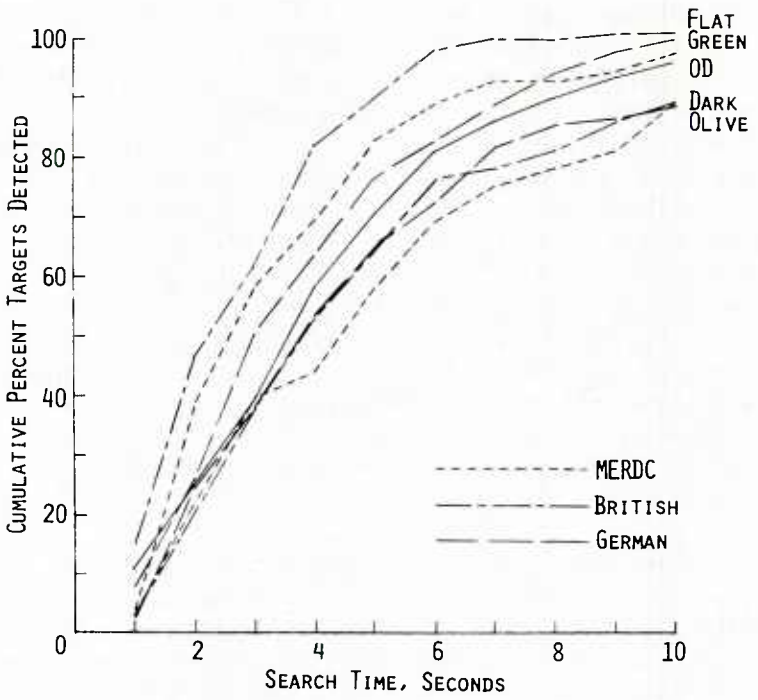

Figure 5. Cumulative Percent Targets Detected as a Function of Search Time.

Table 8. Analysis of Variance of Search Times.

Source of Variation	df	MS	F
Pattern Colors (C)	1	263.99	15.88*
Subjects	11	21.98	NS
Error C	22	16.62	
Pattern Contours (P)	2	2.01	NS
C x P	2	8.63	NS
Error P	44	5.35	
Locations (L)	8	57.09	8.98*
C x L	8	18.37	2.89*
Error L	176	6.36	
P x L	16	6.78	NS
C x P x L	16	4.31	NS
Error PL	352	4.21	

*$p < .01$
NS = Not Significant

Table 9 shows the mean search times at each of the nine locations of the terrain model. The results of a Newman-Keuls test of all possible comparisons of the nine mean search times was included as part of the table. The upper center was associated with significantly longer search times than the lower center and right sectors.

Table 9. Mean Search Time in Seconds at Each of the Nine Locations. The means at the locations which are connected by arrows were significantly different ($p < .01$). None of the other comparisons reached significance.

4.70	5.14	4.74
3.20	4.21	3.97
3.10	2.89	2.79

Far visual acuity scores for each subject in each of the three groups were recorded and correlated with mean search times. The correlation for group 1 and the control group were both significantly greater than zero ($p < .01$). Figure 6 presents scattergrams and correlation coefficients for each group of subjects. The percent of the letters on the chart which each subject correctly identified, starting at 20/20 and continuing through 20/12, were recorded and used for the correlation with search times. There were 20 letters at each level of visual acuity (20/20, 20/17, 20/15, 20/12) so each subject's score was the total number of letters correctly identified divided by 80.

A graph was included which shows mean search times as a function of trial number or serial order for group 1 and group 2 (Fig. 7). Both curves seem to indicate a gradual learning effect. The results of t-tests on the mean search times for the first and last six trials revealed no significant difference for group 2 while the result was significant for group 1 ($t=2.65$, $df=11$, $p < .01$).

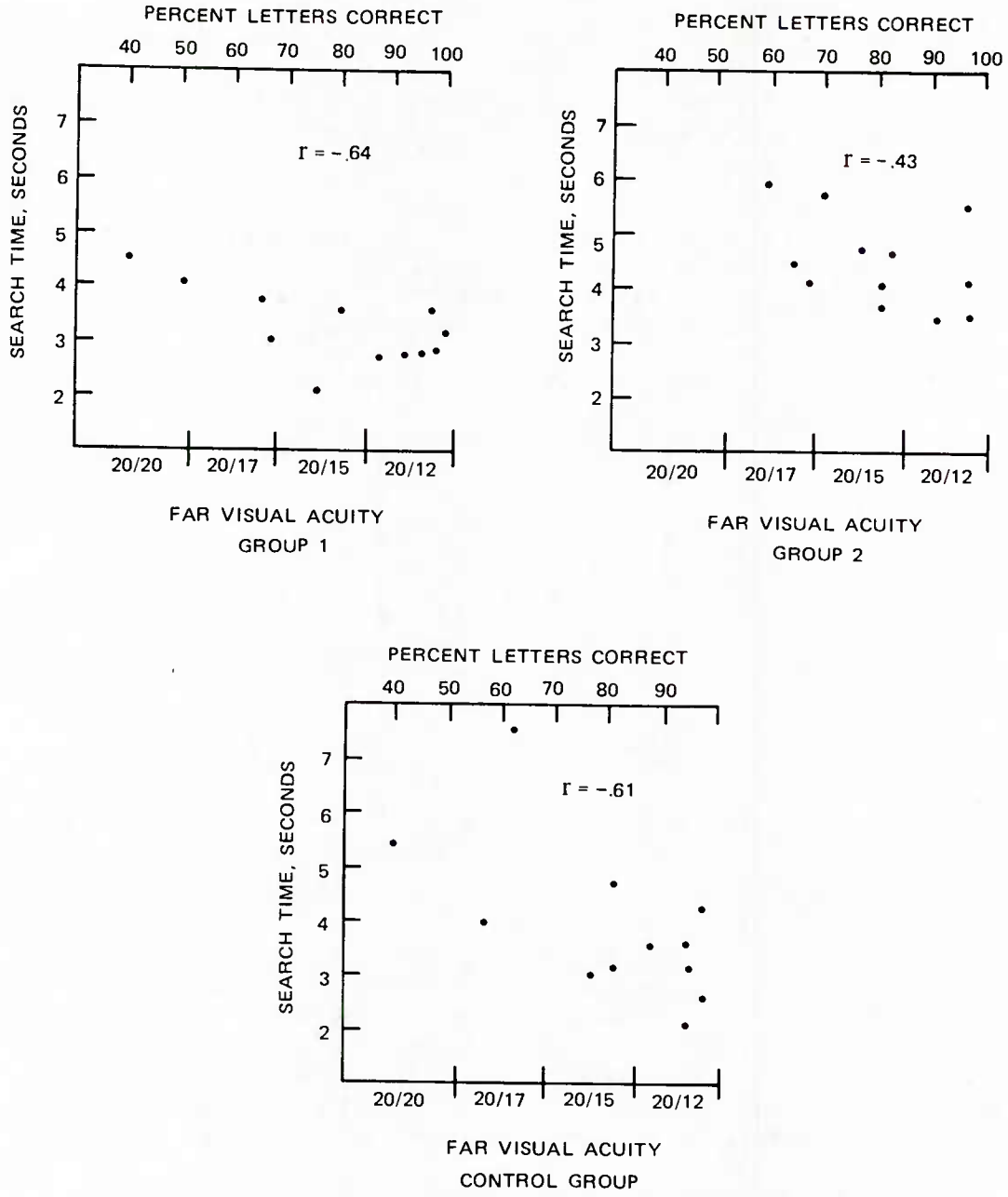

Figure 6. Scattergrams Showing Mean Search Times Plotted as a Function of Far Visual Acuity. The Correlation Coefficient for Each Group is Included.

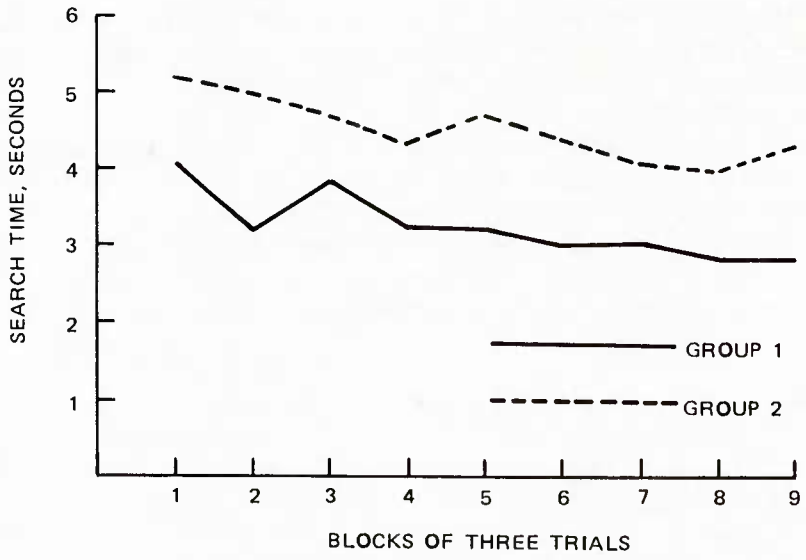

Figure 7. Mean Search Times as a Function of the Trial Number or Serial Order of Trials Received for Two of the Groups. Search Times for the 27 Trials Each Subject Received were Averaged in Groups of Three.

DISCUSSION OF RESULTS

This second experiment also showed that there were no significant differences among pattern contours. The results of both experiments indicate that, for the pattern contours tested (MERDC, Swedish, British, and German), target detection is not affected by pattern contours. This holds even when the vehicles are partially masked from view, as in Experiment I.

An unexpected result of this experiment was the large significant difference between the dark olive patterned targets and the green patterned targets. It was hypothesized that pattern color affects search times but no hypothesis was made concerning which color would be more effective. The colors chosen to paint the vehicles were selected because they were distinctively different colors, yet appeared subjectively to be equally difficult to detect when placed on the terrain model. One explanation for the difference between pattern colors is the difference between the average light luminance of the two groups of targets, with dark olive being lower than green. This explanation is weakened, however, by the fact that the olive drab target, which had a lower luminance value than both the dark olive and green targets, was not significantly harder to detect than either of them. Computation of contrast values offers no explanation either since target-to-background contrast was greatest for the olive drab targets and

least for the flat green targets. The cause of the difference is not clear-cut, but the implication seems to be that if two colors appear equally difficult to detect, it is probably better to go with the darker color.

The significant correlations between mean search times and far visual acuity scores were also an unanticipated outcome of this experiment. The implicit hypothesis was that subjects with 20/20 far visual acuity would perform as well as subjects with 20/12; this because of the large angular subtense of the targets. However, the results indicate that up to 33 percent of the between subject variance can be accounted for by differences in far visual acuity.

The results of Experiment I suggested that there would be no trial-to-trial learning effect, but learning did occur in one of the groups. This fact did not affect the analysis of variance because the presentation order of the patterned targets was completely counterbalanced between subjects. Effects due to learning were evenly distributed across targets. The effect of learning on the comparisons of the patterned targets with the olive drab target was minimized by using the first 18 trials (for the patterned targets) instead of the total 27.

CONCLUSIONS

Spending the time and money necessary to pattern-paint military vehicles with any of the four patterns tested cannot be justified on the basis that the vehicles will be more difficult to detect when (1) diffuse lighting conditions exist, (2) the vehicles are to be camouflaged from the direct vision of airborne observers, and (3) the terrain is similar to that which was simulated for this report. Pattern-painting may be justifiable for other reasons, such as a positive effect on troop morale; it may also be effective for other backgrounds.

Paint color is an important factor. It is not always obvious that one color will provide more effective camouflage than another color. Two colors which appear equally difficult to detect against a particular background may prove to be significantly different when tested in a controlled experiment. For the conditions tested, pattern contours and the number of colors used were not important factors.

For the ranges tested, as far visual acuity improves from 20/20 through 20/12, the probability that an observer will detect a vehicle target in a given period of time increases. This finding suggested that requiring personnel who are involved in such tasks to have corrected far visual acuity to 20/15 or better would improve their search performance.

APPENDIX A

INSTRUCTIONS TO SUBJECTS*

CAMOUFLAGE EXPERIMENT

This is an experiment on camouflage. The purpose of this study is to determine the effect of paint color and pattern on your ability to detect a test target.

Here is the test target. You will see it located randomly in the search area you see through the small window. One and only one target will be seen during each trial.

If you will be seated you can see the search area through the window. One experimenter will place the target in the area while your view is masked by this shutter and flap. When we are ready, this flap will be lowered and you may take about 3 seconds to focus on the "C" on the rear wall. When you are ready, after about 3 seconds, pull this string with your right hand. This lowers the shutter. Immediately begin searching for the target. You will have 10 seconds to locate it. As soon as you see it flip this switch to stop the timer. Flip it only one way. On the next trial you will flip it the other way. If you fail to find the target in 10 seconds, I will call time and raise the shutter. After you find the target and have flipped the switch, please describe the location of the target; i.e., upper left, lower left, upper right, lower right. Do you have any questions?

*This set of instructions was read to each subject for an experiment which preceded Experiment I of this report. Immediately following that experiment, instructions for Experiment I were read.

EXPERIMENT I

Your part in this experiment will be the same as it was in the preceding experiment with one exception. You will be allowed to watch the experimenter walk to, and pick up, the target after you have named the section where you think it is located. If you realize at this point that you did not correctly detect the target, you should say so.

The targets will be these three APC's. Only one target will be presented at a time with each being presented eight times in succession. The experiment will consist of 24 trials total. You will not know which target will be presented first and no announcement will be made when eight trials have been completed and another target is presented.

Do you have any questions?

APPENDIX B

INSTRUCTIONS TO THE SUBJECTS FOR EXPERIMENT II*

This is an experiment in camouflage. The purpose of this study is to determine the effect of several different patterns on an observer's ability to detect test targets.

The targets for this experiment will be these three armored personnel carriers.

If you look through this opening in the wall you will see a square terrain model. I can block your view of the terrain model by pulling up a shutter attached to the wall (shutter is pulled up). However, you can still see the wall above the terrain model. I can block your view entirely by raising a flap above the shutter. (Flap is raised.)

Your task during this experiment will be to search for one of the three targets on the terrain model. When one of the targets is in position on the terrain model an experimenter will say "ready" and the flap will be lowered (flap is lowered). You are to look at the green "C" on the wall for about two seconds then pull the string to lower the shutter. Go ahead and pull the string. You are to begin searching for the target immediately after the shutter falls. You will have ten seconds to search for the target. When you detect the target you must flip the switch which is on the shelf and to your left. This switch stops an electric timer. It has to be re-set before each trial so be sure it is in the start position before the next trial begins. After you have flipped the switch, you are to name the section of the terrain model where the target is located. It will be one of the six locations marked off and identified on the square piece of paper in front of you. Remember to name the location only after you have flipped the switch. If you do not detect the target in ten seconds the experimenter will say "time" and the shutter and flap will be raised.

The targets will be presented one at a time with each being presented eleven times in succession. There are three targets so the experiment will consist of a total of thirty-three trials. Before each set of eleven trials the target you will be searching for will be placed on the front of the terrain model to give you an idea of how it looks.

Do you have any questions?

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*These instructions were played for subjects in groups 1 and 2. Another set of instructions, with minor changes where appropriate, were played for subjects in the control group.

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